Marketing Research Report No. 485

TRANSPORTATION OF HANGING BEEF BY REFRIGERATED RAIL CARS AND 'PIGGYBACK' TRAILERS

U.S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

PREFACE

This study is part of a broad program of research to improve the design and performance of equipment for transporting agricultural products, as a means of improving and expanding the market for farm products.

The purpose of this test was: (1) To determine the ability of late design mechanically refrigerated rail cars and trailers to transport fresh beef at the recommended temperature of 32° to 34° F., and (2) to recommend improvements, where required.

The following companies cooperated in the test: American Stores Company; Burlington Refrigerator Express Company; Chicago, Burlington and Quincy Railroad Company; Fruit Growers Express Company; and Pennsylvania Railroad Company.

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Washington, D. C. June 1961

SUMMARY

In the past few years, mechanically refrigerated "piggyback" trailers (trailers on flatcars) and mechanically refrigerated railroad cars have been used to transport meat and packinghouse products. This test was made to evaluate the performance of some of these vehicles on a typical run between Lincoln, Nebr., and Philadelphia, Pa. Two cars and four trailers were tested.

Thermocouples were placed in each vehicle, before loading, to obtain 13 beef and 6 air temperatures at various locations. An electronic temperature indicator was placed in the caboose. Research workers rode the train, taking temperatures every 2 to 3 hours, day and night.

One car had a cold air system that distributed the air in an envelope, or false wall and ceiling, around the load. The other five vehicles blasted the air directly into the load compartment.

Test results showed that the car with the envelope type of air distribution delivered the beef at a temperature of 33° F., which is within the recommended temperature of 32° to 34° for fresh beef. Temperatures in the other five vehicles varied from 28° to 42° at destination. This spread in temperatures was due mainly to inadequate cold air distribution and thermostats which did not give a true indication of inside temperatures.

Recorders on the refrigeration units of the four trailers showed that they operated at high speed from 1 to 30 percent of the time. The remaining time was at low speed operation, indicating that the units had more than adequate capacity to keep the vehicles refrigerated at the desired temperature.

Diesel fuel consumption varied from .48 to .99 gallon per hour among the six vehicles.

The performance of the vehicles was good. However, improvements are suggested to allow this equipment to hold beef closer within the recommended range of 32° to 34° F. These are: (1) Experiments should be tried on a trailer with two ducts taking the cold air to the rear of the trailer; this should make beef temperatures more uniform. (2) Thermostats should be checked regularly to determine whether they are functioning properly. The sensing bulb should be located so it will give a true indication of inside air temperatures. (3) Further tests should be made to determine the effect of the envelope type of air distribution upon transit shrink (loss of beef weight en route) as compared to other methods of air distribution.

TRANSPORTATION OF HANGING BEEF BY REFRIGERATED RAIL CARS AND 'PIGGYBACK' TRAILERS

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INTRODUCTION

During the past few years, several carriers have been experimenting with mechanically refrigerated railroad cars for hauling meats and packinghouse products; approximatley 160 cars of this type are now in service. Several hundred mechanically refrigerated trailers have been introduced into "piggyback" (trailer on flatcar) service for hauling meat. Previously, only cars refrigerated with crushed ice and salt were used in meat movement by railroad; this type of car is still the most widely used.

The test covered in this report was made on a movement of hanging beef between Lincoln, Nebr., and Philadelphia, Pa. Two mechanically refrigerated cars and four mechanically refrigerated "piggyback" trailers were tested. Performances were measured in terms of temperatures maintained in the vehicles, fuel consumption, and refrigeration charges.

DESCRIPTION OF CARS AND TRAILERS

Figures 1, 2, and 3 show the general construction, loading pattern, location of refrigeration unit, and methods of air distribution of the cars and trailers. Since the air (1A) and air blast (2A) locations were different in each vehicle, the place at which these temperatures were obtained is shown for each car and trailers.

Figure 4 is an interior view of trailers A and D, looking toward the front, and figure 5 is a similar view inside trailers B and C.

Table 1 gives data on the bodies of the cars and trailers. The two cars were different in several respects. However, the four trailer bodies were identical in construction except for insulation in the walls. Trailers A and B had expanded polystrene and glass fiber insulation in the walls; trailers C and D had a foamed type of insulation.

Table 2 gives data on the refrigerating units. The two cars had different makes and models of units. However, trailer A and D had the same type of refrigerating units, and trailers B and C had like units.

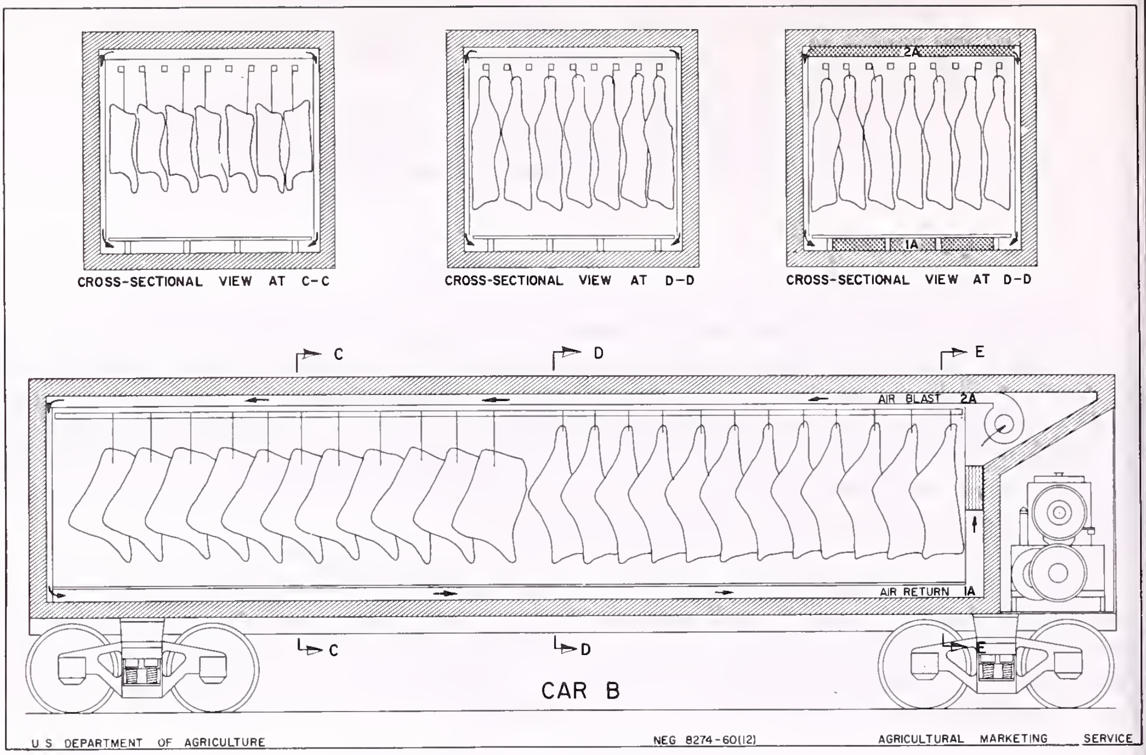

Figure 1.--General construction of Car A, showing loading pattern, location of refrigeration unit, and air blast directly into load.

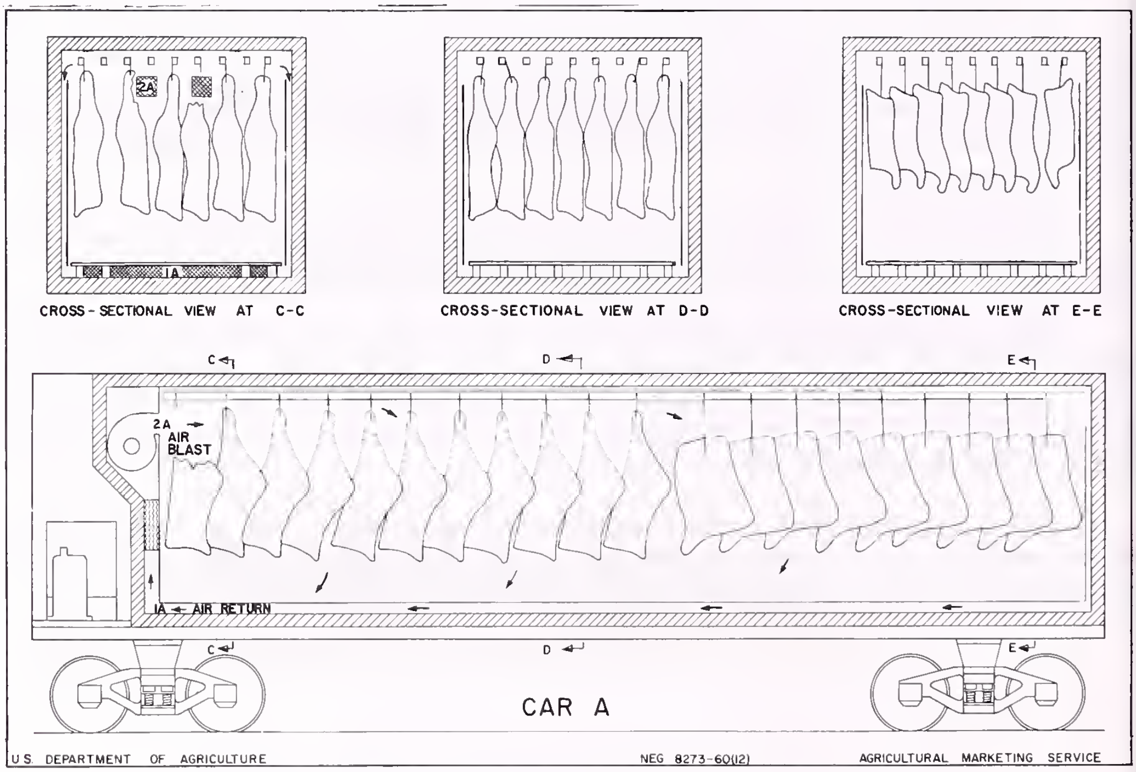

Figure 2.--General construction of Car B, showing loading pattern, location of refrigeration unit, and envelope type of air distribution.

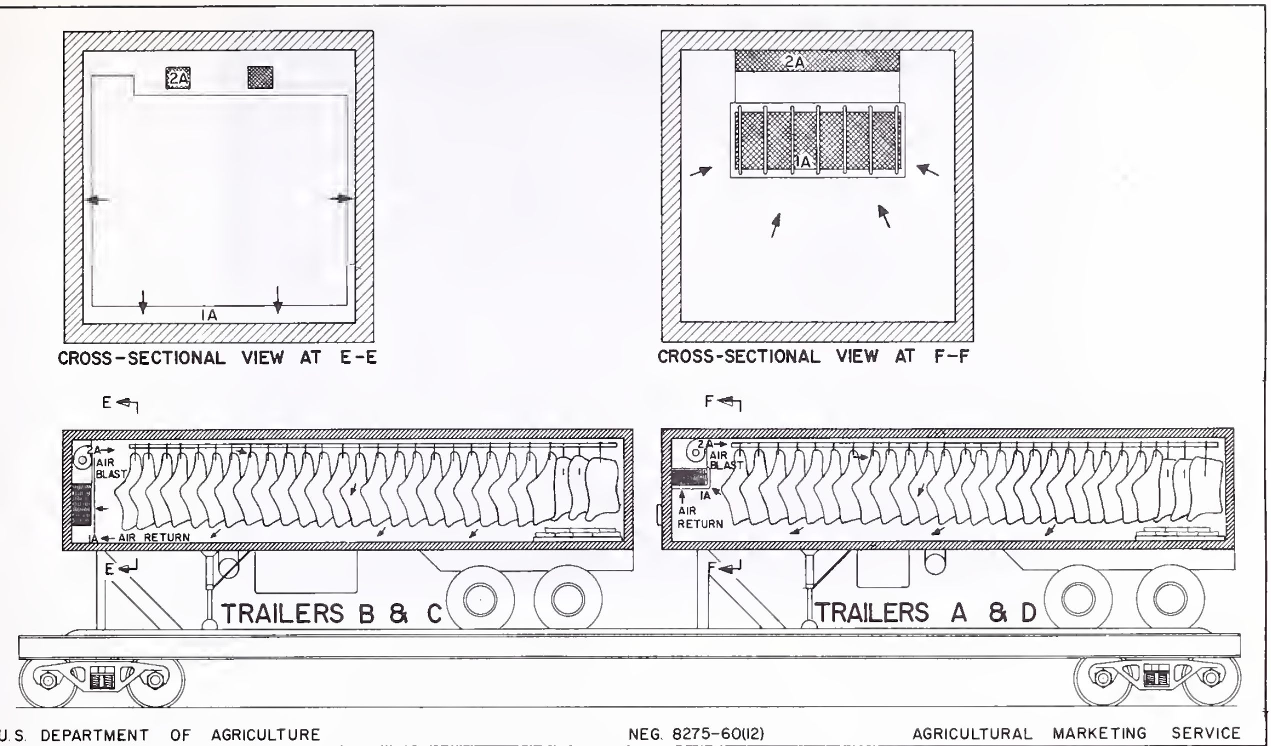

Figure 3.--General construction of trailers A, B, C, and D, showing loading pattern, location of refrigeration unit, and air blast directly into load.

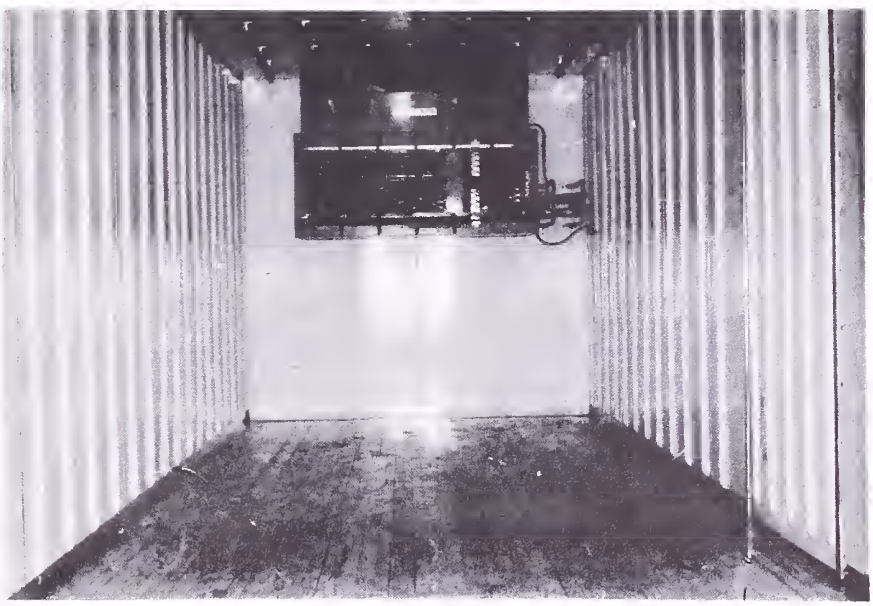

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Figure 4.--Interior of trailers A and D.

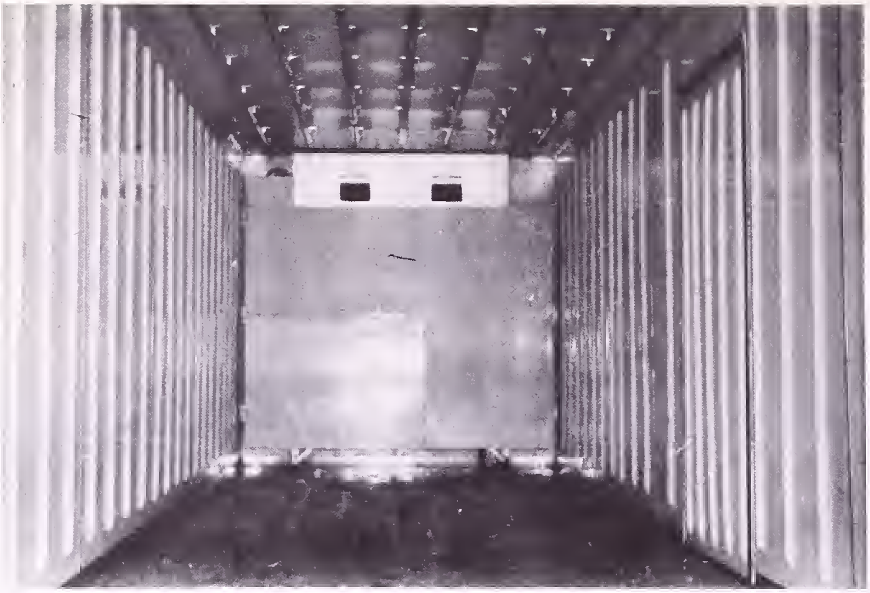

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Figure 5.--Interior of trailers B and C.

Table 1.--Data on car and trailer bodies

Vehicle	Load Limit	Light Wgt.	Inside Lgth.	Inside Width	Inside Hght.	Inside Vol.	Meat Rails	Floor Racks	Insulation			
									Floor	Walls	End	Roof
	Lbs.	Lbs.	Ft.-in	Ft.-in	Ft.-in	Cu.ft	No.					
Car A	98,500	70,500	34-0	8-3	6-9	1,893	9	Yes	6 1/8" foamed-in-place polyurethane.	6 1/8" foamed-in-place polyurethane.	6 1/8" foamed-in-place polyurethane.	9 5/8" foamed-in-place polyurethane.
Car B	93,300	75,700	34-0	8-3	6-3	1,815	9	Yes	6" animal hair	8" glass fiber	8" glass fiber	9" glass fiber
Trailer A	36,000	14,770	33-11	7-3	7-1	1,570	7	No	5" expanded polystyrene	3" expanded polystyrene, 1" glass fiber	4" molded styrene	6" glass fiber
Trailer B	36,000	14,770	33-11	7-3	7-1	1,665	7	No	Same as trailer A	Same as trailer A	Same as trailer A	Same as trailer A
Trailer C	36,000	14,770	33-11	7-3	7-1	1,665	7	No	Same as trailer A	4" foamed polyurethane	Same as trailer A	Same as trailer A
Trailer D	36,000	14,770	33-11	7-3	7-1	1,570	7	No	Same as trailer A	Same as trailer C except 4" styrene in door	Same as trailer A	Same as trailer A

Table 2.--Refrigeration systems in cars and trailers

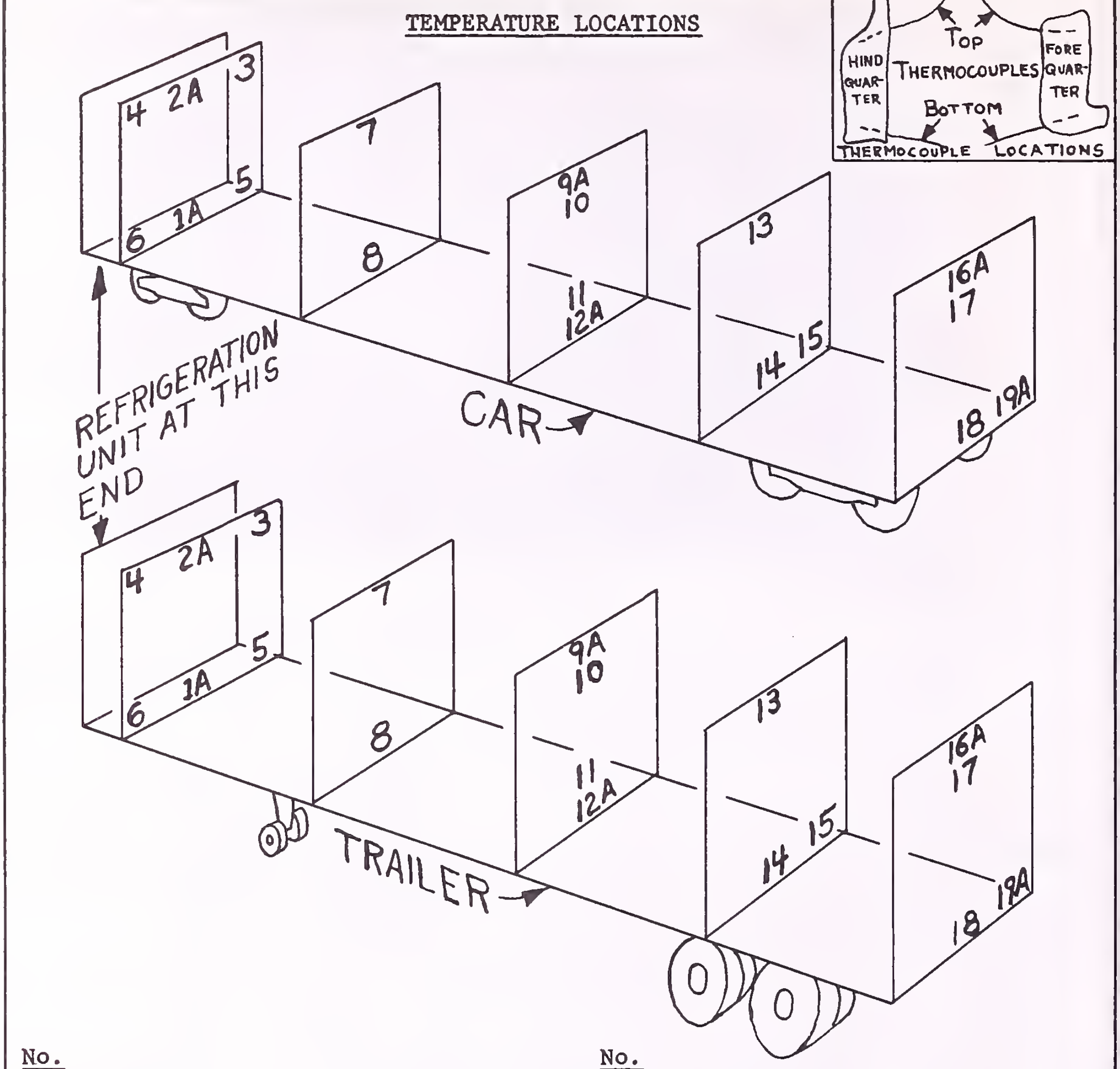
Vehicle	Refrigeration Unit	Method of Cold Air Distribution
Car A	Mechanical, 4-cylinder engine using No. 2 diesel fuel, 24-horsepower at 1,800 r.p.m., 1,200 r.p.m. idling, 12-volt starting system, liquid cooled; 8-cylinder, 10-ton compressor, thermostat range -20° to +70°. Fuel tank 400-gallon capacity.	Cold air is blown from front to rear of car. Side-wall flues are open at top and bottom, with air returning under the floor racks to the cooling coils.
Car B	Mechanical, 2-cylinder engine using No. 1 diesel fuel, 32-horsepower at 1,200 r.p.m., water cooled; 20-kilowatt alternator, 220-volt, 3-phase, 60-cycle; 5-horsepower, semi-hermatic compressor, thermostat range 30° to 70°. Fuel tank 400 gallon capacity.	Cold air is circulated through a semi-envelope system. Air is blown into the false ceiling, down the side and end wall flues, and then under the floor racks to the return air grill.
Trailer A	Mechanical, 4-cylinder engine using No. 2 diesel fuel, mounted underneath trailer with evaporator inside nose of trailer; 12-volt starting system, liquid cooled, thermostat range -10° to +70°. Fuel tank 40-gallon capacity.	Cold air is blown from front toward rear of the trailer, with free return to cooling coils.
Trailer B	Mechanical, 4-cylinder engine using No. 2 diesel fuel, mounted underneath trailer with evaporator inside nose of trailer; 12-volt starting system, liquid cooled, thermostat range -10° to +70°. Fuel tank 40-gallon capacity.	Cold air is blown from front toward rear of the trailer, with free return to the sides and bottom of bulkhead in front of cooling coils.
Trailer C	Same as Trailer B.	Same as Trailer B.
Trailer D	Same as Trailer A.	Same as Trailer A.

TEST PROCEDURE

Each car and trailer was wired with thermocouples prior to loading, in order to obtain 13 beef and 6 air temperatures at the locations shown in figure 6. Top and bottom temperatures in the quarters of beef were taken at the approximate positions shown in the inset sketch. An electronic temperature indicator and switchboard were set up in a caboose as shown in figure 7. Recorders were attached to each trailer refrigerating unit to obtain the times that the unit operated at high and low speed. The thermostats on all vehicles were set by the carrier at 32° F. Test cars were precooled for about 20 hours before loading and the test trailers for about 2½ hours.

The six loads of beef were taken from the same chilling room so that the beef temperatures at loading would be approximately the same for all trailers and cars. Figure 8 shows quarters of beef being removed from an overhead conveyor and loaded into one of the trailers; figure 9 shows a partially loaded car.

All loading was completed between 7:30 a.m. and 11:00 a.m. on July 18. The train left Lincoln, Nebr., at 6:00 p.m., July 18, and arrived in Philadelphia, Pa., at 4:00 p.m., on July 21. Figure 10 shows the test cars and trailers en route. The cars and trailers are designated A, B., etc., according to their order from front to rear of the train.



No.		No.	
1A	Return air	11	Middle, bottom, center
2A	Blast air	12A	Middle, bottom, center air
3	Front, top, right side	13	3/4 length, top, center
4	Front, top, left side	14	3/4 length bottom, center
5	Front, bottom, right side	15	3/4 length, bottom, right side
6	Front, bottom, left side	16A	Rear, top, center air
7	¼ length, top, center	17	Rear, top, center
8	¼ length, bottom, center	18	Rear, bottom, center
9A	Middle, top, center air	19A	Rear, bottom, right side air
10	Middle, top, center		

NOTE: All are beef temperatures except those designated "A" which are air.

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Figure 6.--Locations in cars and trailers at which temperatures were taken. Inset sketch shows top and bottom thermocouples as placed in beef.

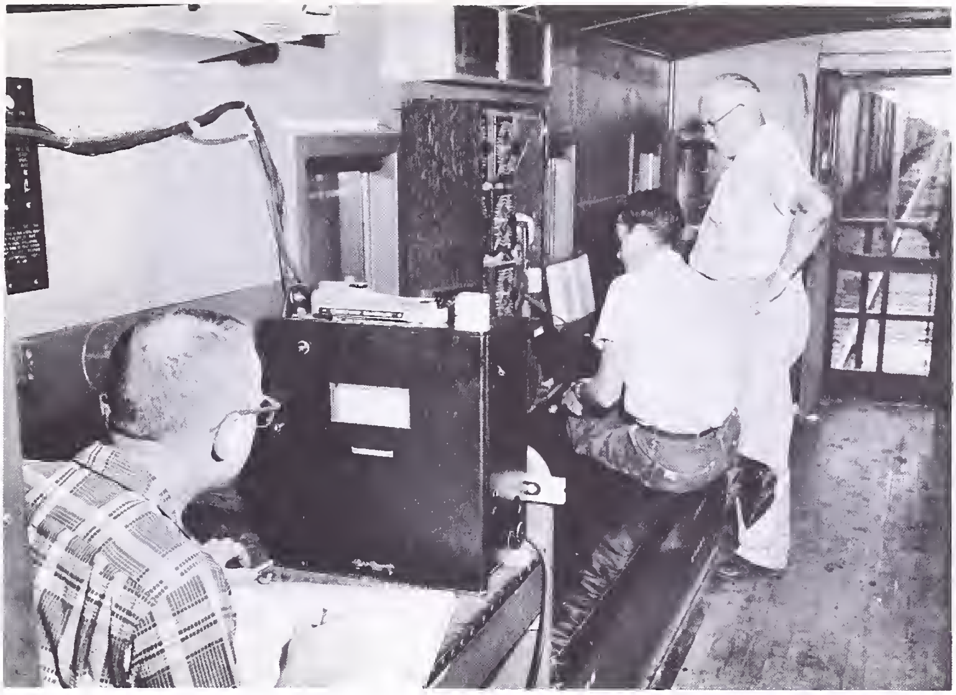

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Figure 7.--Test instruments in caboose.

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Figure 8.--Loading beef from packing plant into one of the trailers.

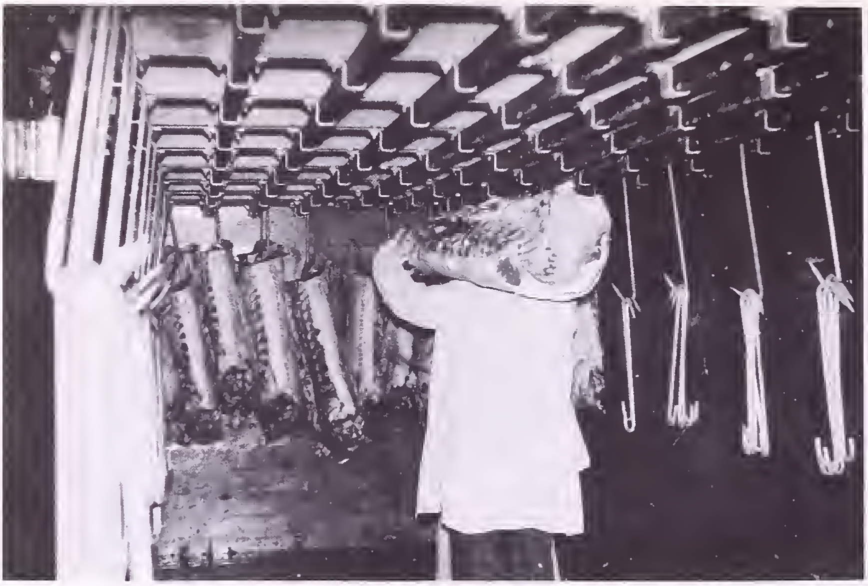

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Figure 9.--Loading one of the cars.

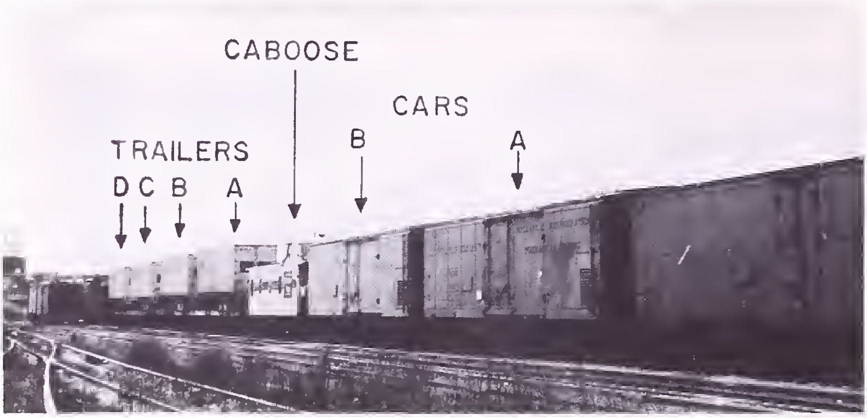

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Figure 10.--Test cars and trailers en route.

The weight of the beef when it was loaded varied from approximatley 26,000 to 32,000 pounds as follows:

Vehicle	Pounds	
Car A	25,874	
Car B	26,311	
Trailer A	28,439	(includes 169 lb. of boxed meat on floor)
Trailer B	29,227	(Do.)
Trailer C	32,024	(Do.)
Trailer D	30,475	(Do.)

Figure 11 shows foam rubber strips around the sides and top of three of the loading doors at the packing plant where the trailers were loaded. These strips were approximatley 12 by 12 inches in cross section. Figure 12 shows a trailer backed against this foam rubber, thereby preventing the warm outside air from entering the trailer. The meat was moved directly from the refrigerated plant into the trailer. The interior of the trailer stays cooler when this arrangement is used than when the meat is moved across open loading docks into the trailer.

Temperatures were taken in each car and trailer every 2 to 3 hours throughout the entire trip. After the train arrived at Philadelphia, temperatures were taken in the stationary vehicles approximately every 12 hours. Car B was unloaded the next day, Friday, July 22. Car A and the four trailers were held over the weekend, July 23 and 24, and unloaded on Monday, July 25.

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Figure 11.--Foam rubber strips (indicated by arrows) around doors at which trailers are loaded.

TEST RESULTS

Figures 13 through 18 show averages of air and beef temperatures, taken at the locations shown in figure 6, for each car and trailer, as follow:

	Average of Temperatures
Air, average above load	9A and 16A
Air, average below load	12A and 19A
Beef, average top	3, 4, 7, 10, 13, and 17.
Beef, average bottom	5, 6, 8, 11, 14, 15, and 18.

Beef Temperatures

Car B did the best job of cooling its load down to the recommended temperature of 32° to 34° F. At destination, car B had a temperature spread of only 33° to 33.4°; temperatures in the other five vehicles varied from 28.2° to 43.7° (table 3).

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Figure 12.--Trailer backed against foam rubber (indicated by arrows) at loading door.

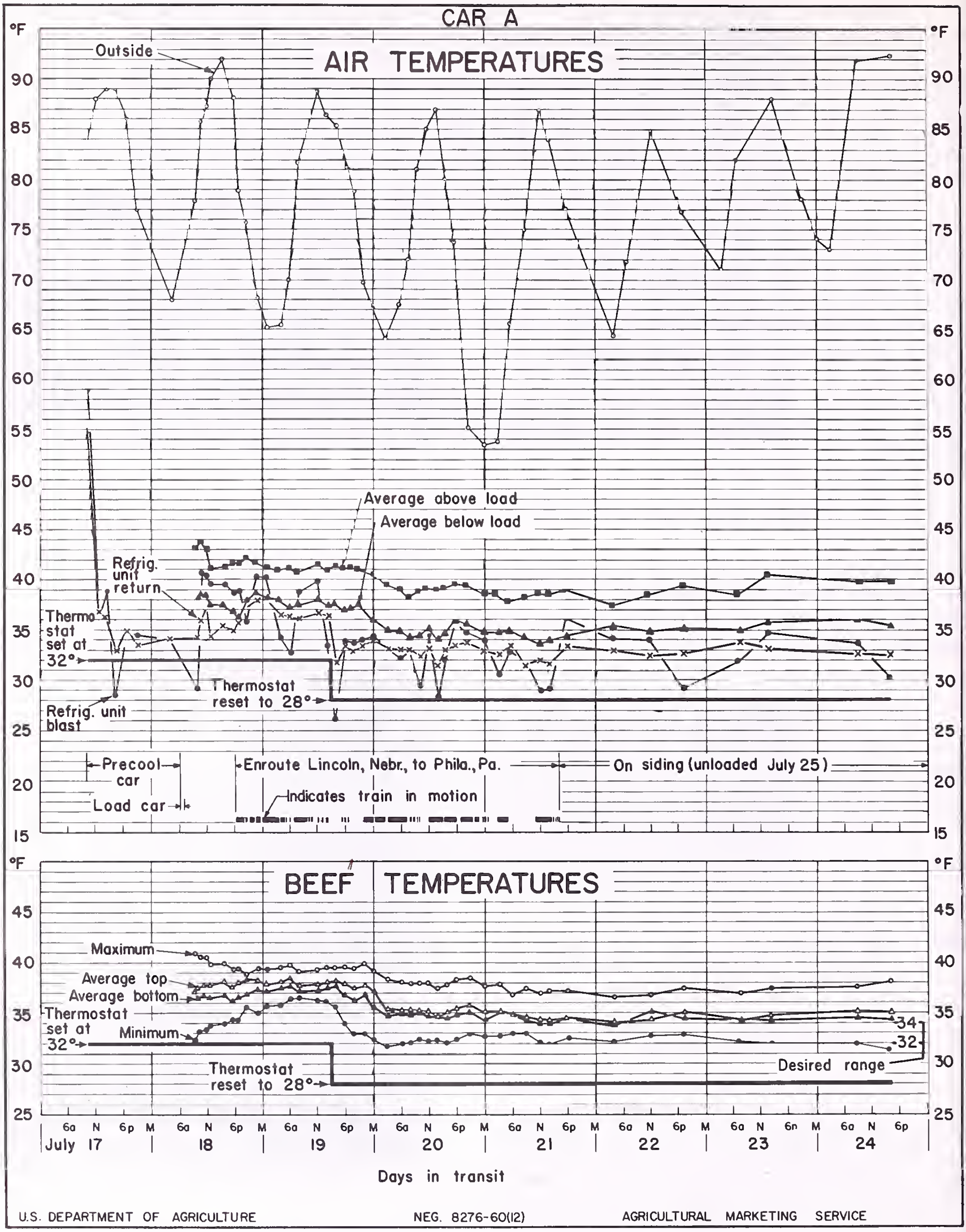

Figure 13.--Temperatures in car A which blasted air directly into load.

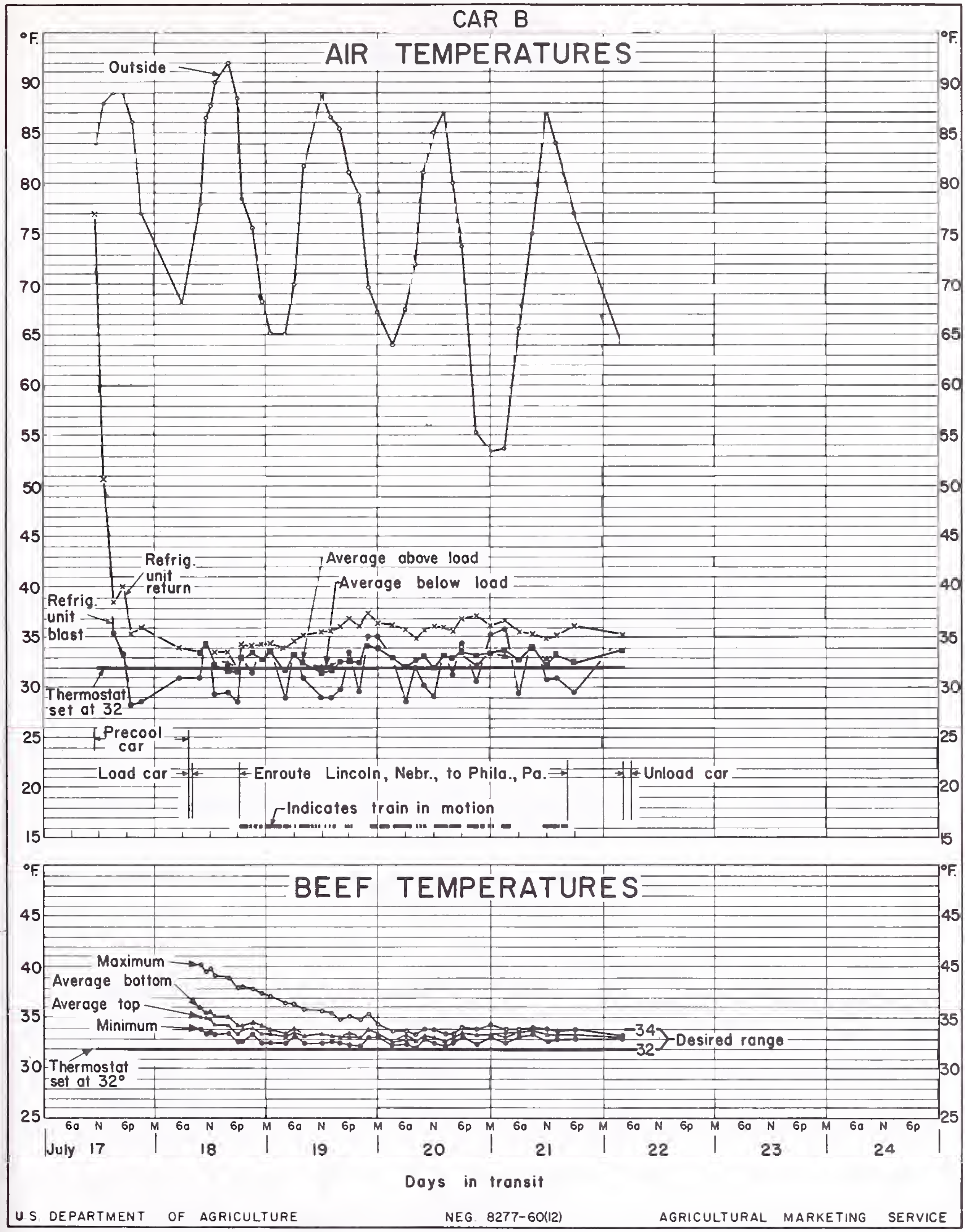

Figure 14.--Temperatures in car B with envelope type of air distribution.

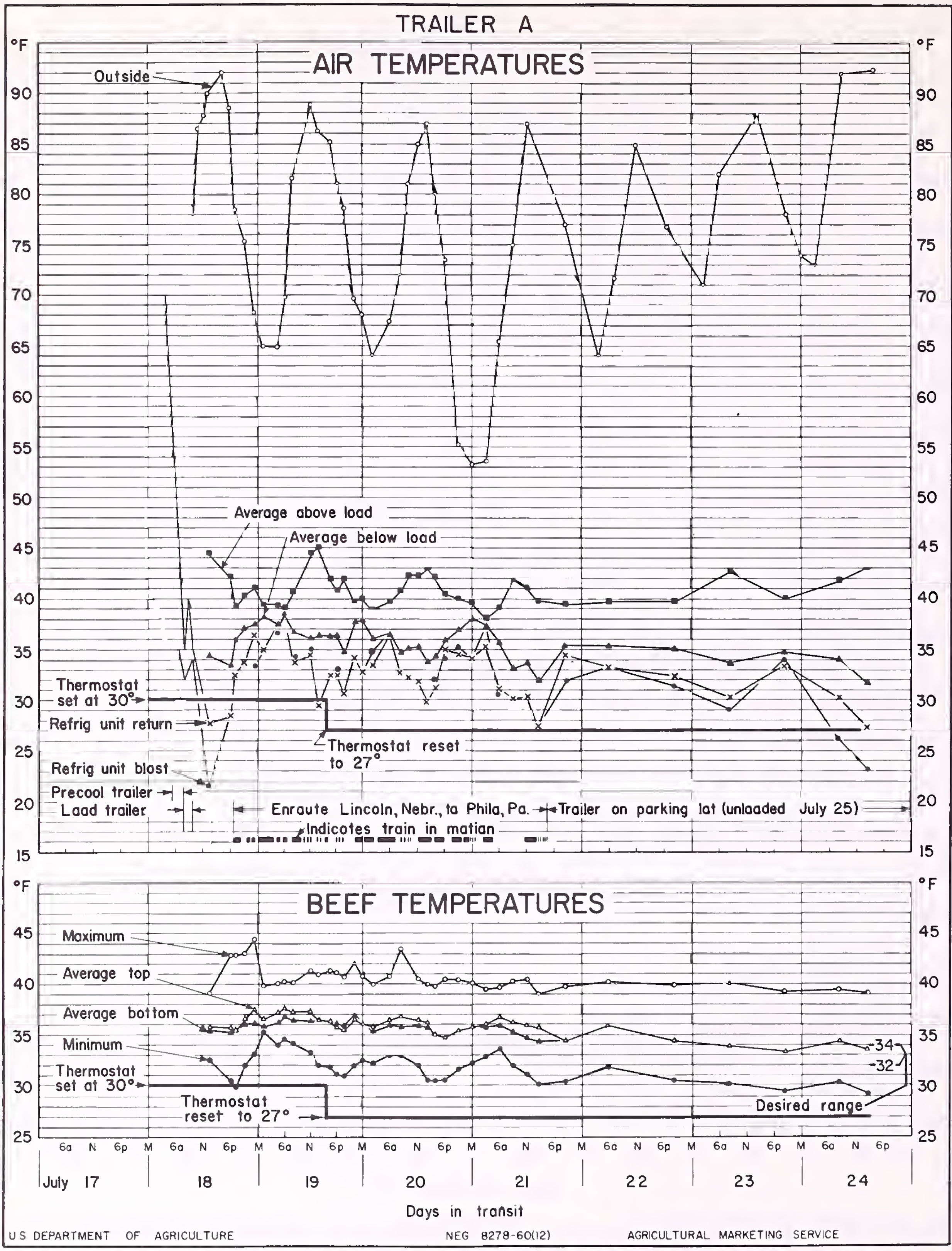

Figure 15.--Temperatures in trailer A which blasted air directly into load.

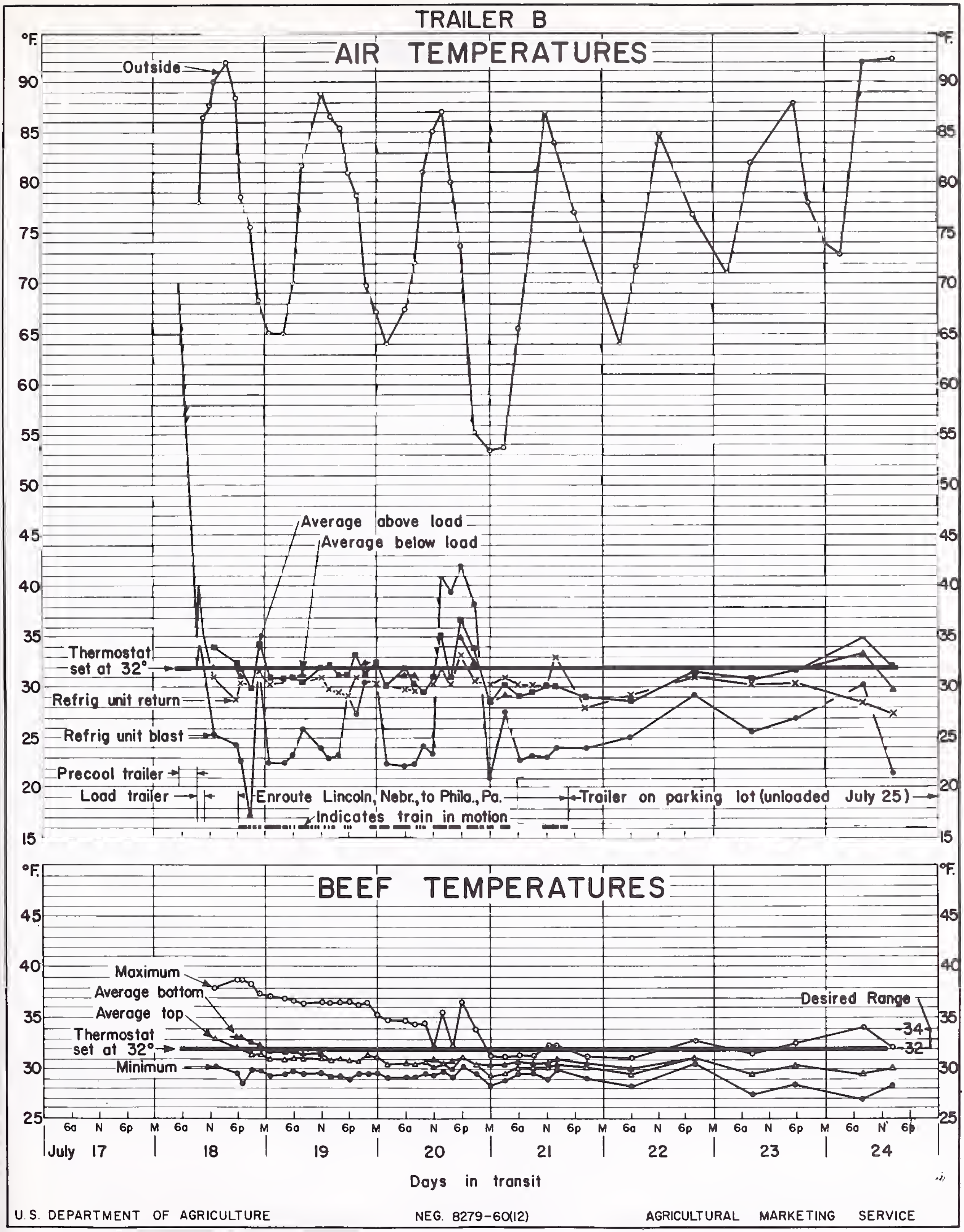

Figure 16.--Temperatures in trailer B which blasted air directly into load.

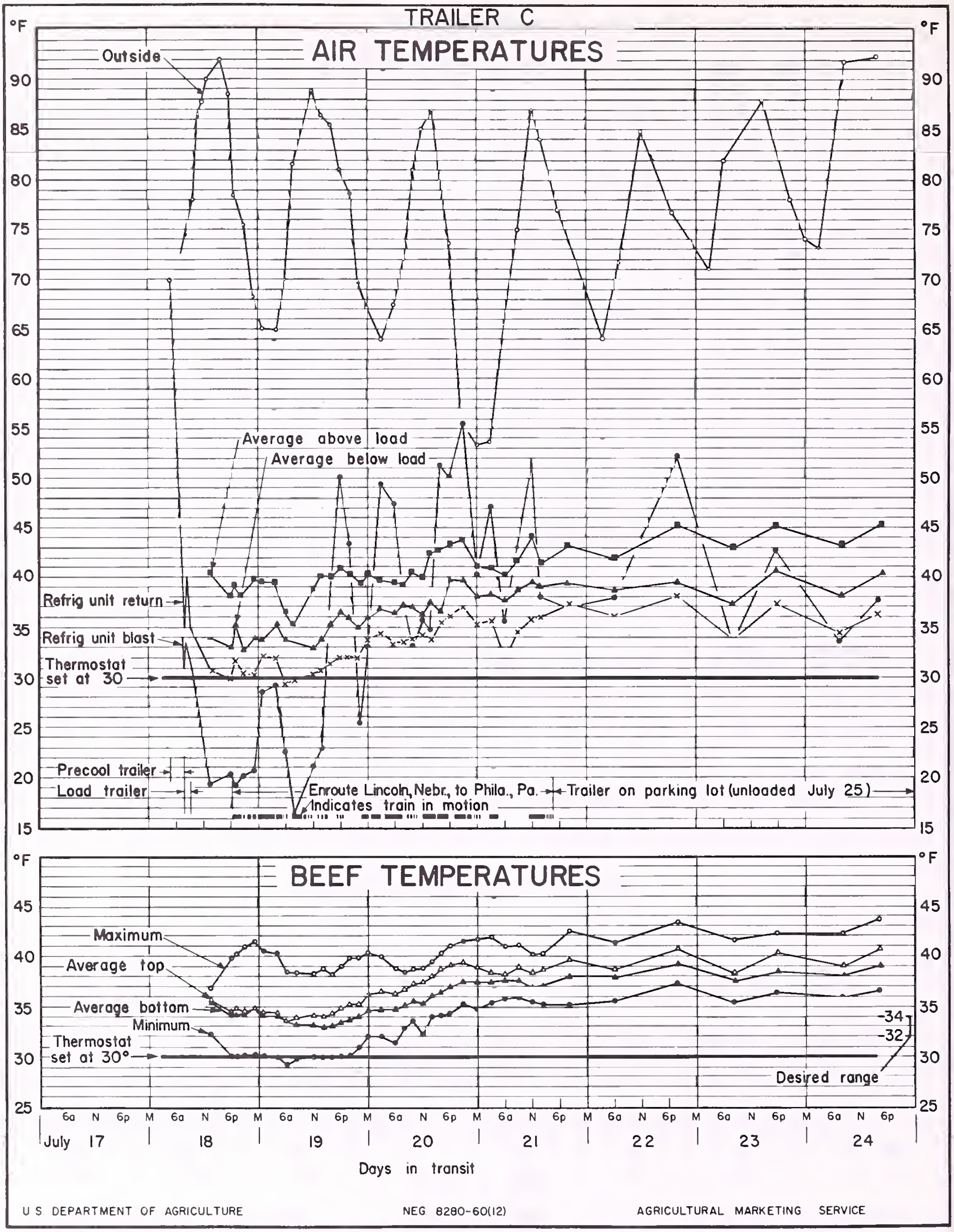

Figure 17.--Temperatures in trailer C which blasted air directly into load.

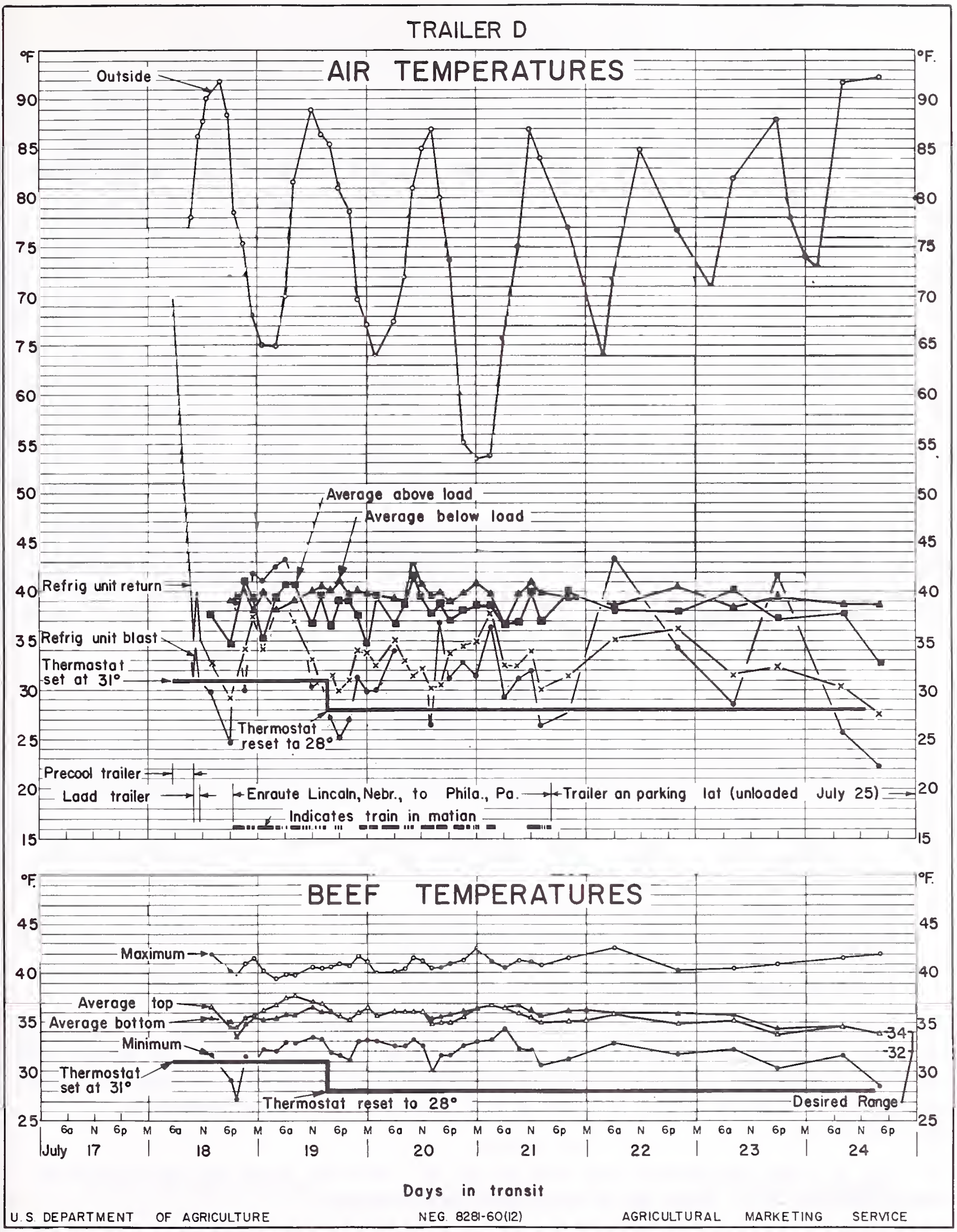

Figure 18.--Temperatures in trailer D which blasted air directly into load.

Table 3.--Beef temperatures in cars and trailers

Vehicle	Temperature at loading			Temperature at destination		
	Avg., top	Avg., bottom	Spread min. to max.	Avg., top	Avg., bottom	Spread, min. to max.
	°F.	°F.	°F. to °F.	°F.	°F.	°F. to °F.
Car A	37.0	37.8	32.3 to 41.0	35.0	34.3	31.3 to 38.1
Car B	35.0	36.0	34.0 to 40.0	33.1	33.1	33.0 to 33.4
Trailer A	35.8	35.5	32.6 to 39.1	33.6	33.6	29.2 to 39.1
Trailer B	33.0	33.0	30.1 to 38.0	30.1	30.1	28.2 to 32.1
Trailer C	35.8	35.4	32.2 to 36.9	40.8	39.0	36.6 to 43.7
Trailer D	36.7	35.4	31.8 to 42.0	34.0	34.0	28.6 to 42.0

Data taken during the trip show that, with few exceptions, the highest beef temperatures in car A and all trailers occurred at positions 13, 15, 17, and 18 at the rear quarter of the vehicles (fig. 6). The lowest beef temperatures for these vehicles occurred at positions 4, 5, 6, 7, 8, and 11 in the front half of the vehicles.

Thermostat Settings

Car A.--The thermostat was originally set at 32° F. On the second day, thermocouple readings showed that the beef was not cooling as expected. The thermostat was reset to 28° at 3:30 p.m. on July 19. After the fifth day, on July 24, the following approximate temperatures were noted:

Air, average above load....................................40°
Air, average below load....................................36°
Air, refrigeration unit blast...............................34°
Air, refrigeration unit return.............................33°
Beef, average top..35°
Beef, average bottom.......................................34°

The refrigeration unit return (33°) was 5° higher than the thermostat setting; the beef (34°) was 6° higher than the thermostat setting. Thus, it would seem that the thermostat was not functioning properly or that the sensing bulb was located in the wrong place to give a true picture of inside commodity temperatures.

Car B.--The thermostat was set at 32° F., and the beef was delivered at approximately 33°. This was a very good performance.

Trailer A.--The thermostat was supposedly set at 32° F. However, it was actually set at 30°. This error was probably due to the location of the thermostat, high on the nose of the trailer, which did not allow easy access for setting the dial. In addition, the dial was about one-half inch away from the face of the instrument, which allowed a variation in setting, depending upon the angle of vision of the operator. On the second day, July 19, the thermostat was reset to 27°. When delivered, the beef was about 34°, or 7° higher than the thermostat setting.

Trailer B.--The thermostat was set at 32° F. At the end of the trip, the refrigerating unit return was approximately 27° and the average beef temperature was about 30°. Thus, actual temperatures were from 2° to 5° below the thermostat setting. Among the trailers, this one held the closest range of minimum and maximum beef temperatures.

Trailer C.-- Here, as with trailer A, the thermostat was set at 30° F. instead of 32° at the start of the trip. Figure 17 shows a gradual rise in inside air and beef temperatures during the trip. The average beef temperature at destination was approximatley 40°. It is probable that there was some malfunction in the refrigerating unit which prevented it from operating at full capacity.

Trailer D.--The thermostat was originally set at 31° F. instead of 32°, as intended. It was reset to 28° on the second day. At the end of the trip the refrigerating unit return temperature was 28°. The average beef temperature was 34°, or 6° higher than shown by the thermostat setting.

Trailer Refrigeration Units

The record of high and low speed of each trailer refrigeration unit was obtained from the recorders for the 148-hour period from 5:00 a.m., July 18, to 9:00 a.m., July 24. The units operated from 1 to 30 percent of the time at high speed. However, no particular significance is attached to these figures as there is no direct correlation with the figures for fuel consumption. The percent of time that each unit operated at high and low speed was:

Trailer	High Speed Percent of time	Low Speed Percent of time
A	4	96
B	25	75
C	30	70
D	1	99

Fuel Consumption

The average hourly rate of fuel consumption for each vehicle during the trip was:

Vehicle	Type of Fuel	Consumption per hour Gallons
Car A	Diesel No. 2	.51
Car B	Diesel No. 1	.99
Trailer A	Diesel No. 2	.48
Trailer B	Diesel No. 2	.53
Trailer C	Diesel No. 2	.67
Trailer D	Diesel No. 2	.50

TRANSPORTATION CHARGES

Transportation charges to the shipper were:

Vehicle	Minimum weight Pounds	Actual weight Pounds	Freight rate per 100 lb. Dollars	Freight charge Dollars	Refrigeration charge Dollars	Total charge Dollars
Car A	25,000	25,874	2.52	652.02	95.06	747.08
Car B	25,000	26,311	2.52	633.04	95.06	758.10
Trailer A	25,000	28,439	2.69	765.01	0	765.01
Trailer B	25,000	29,227	2.69	786.01	0	786.21
Trailer C	25,000	32,024	2.69	861.45	0	861.45
Trailer D	25,000	30,475	2.69	819.77	0	819.77

CONCLUSIONS

The performance of all of the cars and trailers could be termed good, since they delivered the meat in good condition. Car B might be termed excellent, because it delivered the meat within the recommended temperature of 32° to 34° F.

Beef temperatures are kept more uniform by distributing the air around the load than by blasting the air into the load. Therefore, a duct down each side of the trailer at the ceiling would probably improve trailer performance. The semi-envelope design in car B provided the best air distribution for the two rail cars tested.

The thermostat dial on all trailers should be at eye level height for easy access and accurate setting.

Four of the six thermostats in the test vehicles did not give a true indication of the inside air temperature. There are several possible reasons for this discrepancy. One may be inaccurate calibration of the thermostat. However, a discrepancy between the thermostat and air temperatures in motor-truck trailers has also been found in other tests.

In Car A and three of the trailers the thermostat setting and the temperature of the air returning to the refrigeration unit were colder than the average air temperatures in other locations. This would indicate that the thermostat, if accurately calibrated, did not have its sensing bulb properly placed in the vehicle to reflect an average of air temperatures around the load. The course the air will take, when it is released from the refrigerating unit, is determined by the type and pattern of the load, whether a forward bulkhead is used to minimize short-circuiting of the cold air or ducts are used for more uniform distribution. Additional research is required to determine where the thermostat bulb should be placed.

Because the receiver was unable to furnish weights at unloading, no comparison of transit shrink could be made. Tests should be made to determine if transit shrink is different with the semi-envelope type of air distribution compared to air ducted into the load.

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